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Aquatic Invertebrate Monitoring at Pea Ridge National Military Park, 2009-2010

Natural Resource Data Series NPS/HTLN/NRDS—2012/240

ON THE COVER
Winton Spring Branch, Pea Ridge National Military Park, Arkansas
Photograph by: The NPS Heartland Inventory and Monitoring Network

Aquatic Invertebrate Monitoring at Pea Ridge National Military Park, 2009-2010

Natural Resource Data Series NPS/HTLN/NRDS—2012/240

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Abstract

In 2009, the Heartland Inventory and Monitoring Network (HTLN) of the National Park Service (NPS) began monitoring aquatic invertebrate communities to assess water quality at Pea Ridge National Military Park (PERI). Initial sampling of Pratt Creek and Winton Spring Branch were conducted in May 2009, and Lee Creek was sampled in May 2010. Mean taxa richness ranged from 15-25 taxa among the three streams and mean EPT richness ranged from 6 to 16 genera. Diversity measures (Shannon's index, Evenness, and EPT ratio) indicated moderate species richness and evenness reflecting the dominance of a few tolerant taxa among samples. Hilsenhoff Biotic Index mean scores ranged from 5.48 to 5.79, indicating a moderately tolerant community structure. Although the streams do not appear to be impaired, data are currently insufficient to fully characterize their integrity. Prevailing conditions including intermittent flow in Pratt and Lee creeks and thermal constancy and stability in Winton Spring Branch may naturally affect the community structure in those streams. Water quality data were well within the Arkansas water quality standards. Additional monitoring will allow insight into any patterns that may exist in and among community structure dynamics in these streams.

Acknowledgments

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Introduction

Aquatic invertebrates are an important biological tool for understanding and detecting changes in stream ecosystem integrity, and can be used to reflect cumulative impacts that cannot otherwise be detected through traditional water quality monitoring. The National Park Service (NPS) began monitoring water quality and invertebrate community structure in Pratt Creek and a tributary (Winton Spring Branch) at Pea Ridge National Military Park (PERI) in 2009 (Bowles *et al.* 2008). An additional tributary of Pratt Creek (Lee Creek) was not included in the monitoring plan initially because it was thought to have intermittent flows during most of the year. Because this tributary was later found to maintain base flow during most of the year, it was included in the sample frame beginning in 2010. Pratt Creek originates in the eastern part of PERI south of the Elk Horn Tavern historical site (Figure 1). It flows in a southwest direction for approximately 2.3 kilometers through restored prairie grasslands and forest where it exits the southern park boundary and flows another 5.1 kilometers before its confluence with Little Sugar Creek. Winton Spring Branch issues from a limestone outcropping approximately 25 meters north of the park road and flows through a forested area for approximately 130 meters to its confluence with Pratt Creek. Lee Creek originates in the center of the park and flows through a forested area for approximately 3.25 kilometers to its confluence with Pratt Creek. Both Winton Spring Branch and Lee Creek flow into Pratt Creek outside of the southern park boundary. Although spring fed, portions of Pratt and Lee Creeks occasionally become losing reaches during the summer season and are dewatered or have only isolated pools. Little is known of the springs' recharge areas. The monitoring objectives of this study, as described by DeBacker *et al.* (2005), are to: 1) determine the status and trends of invertebrate species diversity, abundance, and community metrics, and 2) relate the invertebrate community to overall water quality through quantification of metrics related to taxa richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat condition. The purpose of this report is to summarize baseline aquatic invertebrate monitoring data collected during May of 2009 and 2010.

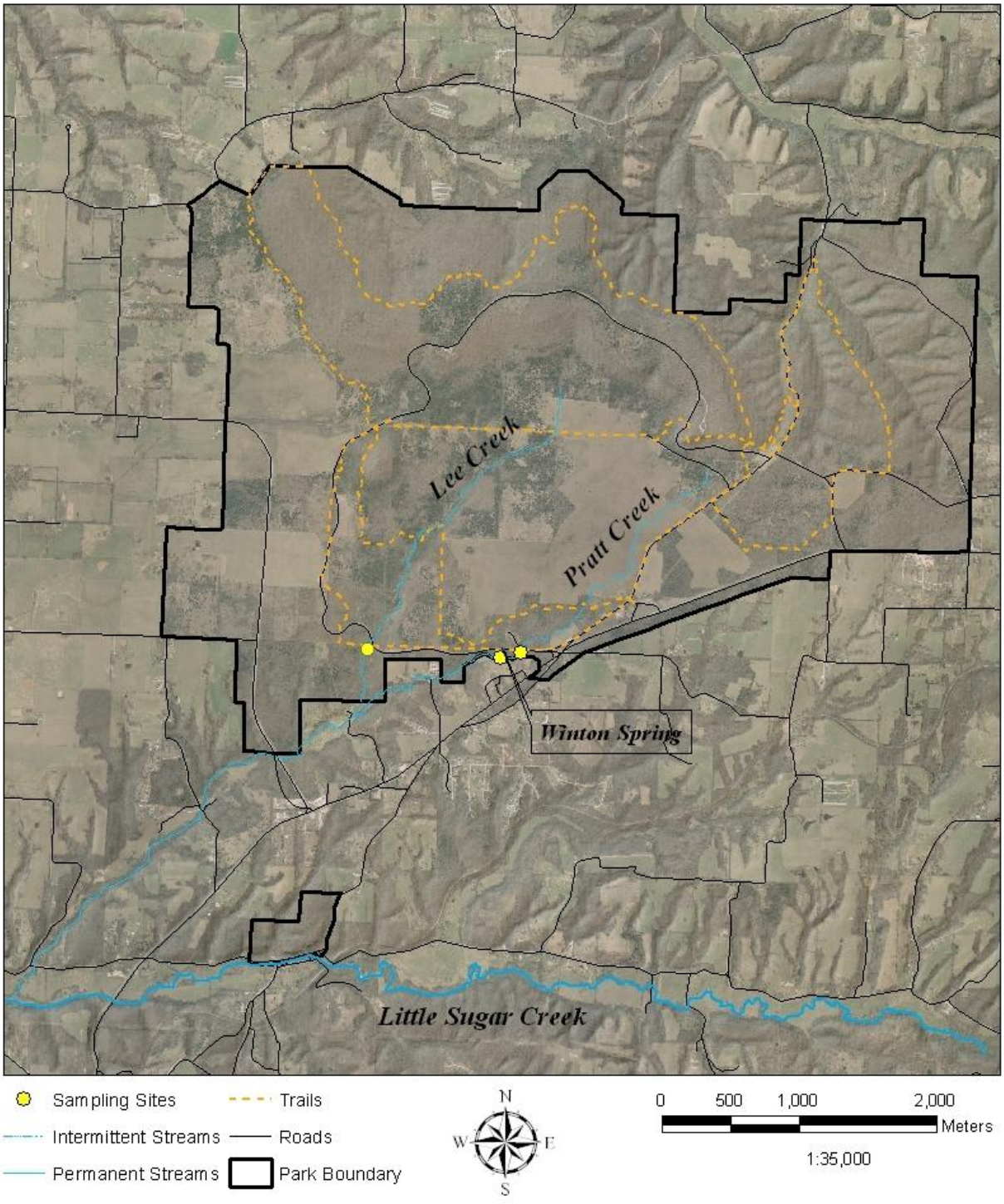

Figure 1. Map showing the approximate lower sampling reach boundary (yellow dot) for Pratt Creek, Winton Spring Branch, and Lee Creek at Pea Ridge National Military Park.

Methods

Methods and procedures used in this report follow Bowles *et al.* (2008). Samples were collected at one reach of Pratt Creek on May 1, 2009, Winton Spring Branch on May 4, 2009, and Lee Creek on May 12, 2010 (Figure 1). Three successive riffles were sampled within each reach with three benthic invertebrate samples collected at each riffle, resulting in nine samples per reach. A Surber stream bottom sampler (500 µm mesh, 0.09 m^2) was used to collect the samples.

Samples were sorted in the laboratory following a subsampling routine described in Bowles *et al*. (2008). Taxa were identified to the lowest practical taxonomic level (usually genus) and counted. Metrics calculated for each sample included percent (%) intolerant taxa (tolerance value $\leq$3.0), percent (%) EPT (Ephemeroptera, Plecoptera, Trichoptera), EPT ratio (EPT density/ (EPT density + Chironomidae density)), family richness, taxa richness, EPT richness, Shannon's Index, taxa evenness (where 0 = minimum evenness, 1 = maximum evenness), and the Hilsenhoff Biotic Index (HBI) (Bowles *et al.* 2008). For details on calculating and interpreting metrics used in this report refer to Bowles *et al.* (2008). Higher metric values are associated with better stream conditions, except for HBI where smaller values indicate better conditions. An increase in HBI is undesired because that would reflect increasing tolerance of the community to disturbance.

In addition to the individual community metrics, we assessed the biotic integrity of the three streams using the Missouri Stream Condition Index (SCI). The SCI is a multimetric index founded on the reference site approach and based on data collected from a variety of streams in different ecoregions (Rabeni et al. 1997). Although developed for Missouri streams, this index is applicable to the streams at PERI because they are in the same ecoregion and have similar physical, chemical and biological characteristics. The SCI is based on scores from four metrics that were chosen as sound measures of community structure and balance (Rabeni et al. 1997, Barbour et al. 1999). They include taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness, Shannon's diversity index, and the Hilsenhoff Biotic Index (HBI). Those four metrics are generally considered sufficiently sensitive to detect a variety of potential pollution problems.

Metric scoring for the SCI follows Rabeni et al. (1997). The index has separate scoring criteria for prairie and Ozarkian streams. All metric values included in the SCI are normalized so that they become unitless, are comparable, and have equal influence on the overall score. The lower or upper quartile of the distribution for each metric is used as the minimum value representative of reference conditions. Ranges for each metric and the assigned scores based on the reference distribution generated are shown in (Table 1). Each metric score is determined by averaging the metric values from the nine samples. The four scores are then summed to generate the SCI score. Scores range from 16-20 for not impaired, 10-14 for impaired, and 4-8 for very impaired (Table 1).

Table 1. Descriptive statistics and scores for the Prairie and Ozark reference stream metrics for the spring index period based on single habitat coarse substrate (riffle) data (Rabeni et al. 1997).

	Statistics					Scores		
Metrics	1%	25%	50%	75%	99%	5	3	1
Prairie Streams								
Taxa Richness	10	15	18	20	29	>=15	14-8	<8
EPT Richness	3	4	5	7	11	>=4	3-2	<2
Biotic Index	5.6	5.8	6.3	6.6	7	<=6.6	6.7-8.3	>8.3
Shannon's Index	1.48	1.77	2.05	2.49	2.6	>=1.77	1.76-0.88	<0.88
Ozark Streams								
Taxa Richness	15	22	27	28	36	>=22	21-11	<11
EPT Richness	4	9	12	15	16	>=9	8-5	<5
Biotic Index	3.7	4.4	4.8	5.3	6.2	<=5.3	5.4-7.7	>7.7
Shannon's Index	1.64	2.47	2.7	2.81	3.18	>=2.47	2.46-1.25	<1.23

Scoring: 16-20 not impaired, 10-14 impaired, 4-8 very impaired.

SCI scores were calculated on data presented in this report for a spring index period using both the Ozark and Prairie criteria, in addition to a composite index score based on these two criteria. The composite score is the average of the Prairie and Ozark scores. Although PERI is in the Ozark ecoregion, its proximity to the South Central Plains ecoregion and the tendency for seasonal drying of the streams lends them qualities of each ecoregion type. In addition, most of Pratt Creek to its confluence with Winton Spring Branch flows though restored prairie thus giving it physical characteristics not unlike those of prairie streams. Because the streams at PERI do not fit nicely into either the Prairie or Ozark categories, the composite score may be more reflective of the actual ecological functioning of these streams.

For each sample, current velocity (meters/second) and depth (cm) were recorded directly in front of the sampling net frame. Qualitative habitat variables (embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were estimated within the sampling net frame as percentage categories (Absent (0%), Sparse (<10%), Moderate (10-40%), Heavy (40-75%), and Very Heavy (>75%)). Habitat data were analyzed as midpoints of each category. Dominant substrate size from the area within the sampling net frame was visually assessed using the Wentworth scale (Wentworth 1922). Stream discharge was measured upstream of the sampled riffles. Temperature (^{o}C), dissolved oxygen (mg/liter), pH, specific conductance (µS/cm), and turbidity were recorded in each stream using a calibrated YSI 6920 data logger. Measurements were made hourly in Pratt Creek and Winton Spring Branch and included a diel period. For Lee Creek measurements were made every 15 minutes during the time invertebrates were sampled and did not include a diel period. The water quality and habitat data presented in this report represent only a snapshot of the broad temporal range of conditions and should be cautiously interpreted. They are intended to describe the prevailing conditions that influence the structure of invertebrate communities, and they may help explain variability between samples, but they should not be used as an analytical tool in the strictest sense (Bowles *et al.* 2008). Due

to the limitations of using water quality data obtained with data loggers, the invertebrate community is used here as a surrogate of the long-term water quality condition of the three streams.

The intent of this study is to monitor community condition of these streams over time (Bowles *et al.* 2008). Because sample size presently is small (n=1 year), a statistical analysis of the data cannot be accomplished and only summary statistics are presented in this report.

Results

Family, taxa, and EPT richness values were higher for Lee Creek in comparison to the other two streams (Table 2). Mean percent EPT was highest for Winton Spring Branch (42.11%) and lowest for Pratt Creek (23.33%). Mean taxa and EPT richness values for all three streams were at or above the minimum range values for regional Ozark reference streams identified in Table 1 (Rabeni *et al.* 1997). The EPT ratios for Winton Spring Branch (0.79) and Lee Creek (0.72) were relatively high because the dipteran family Chironomidae did not represent a substantial portion of the benthic community among samples (<15%). The EPT ratio for Pratt Creek was somewhat lower (0.47); the percentage composition of Chironomidae was 31.07%. Mean percent intolerant species for all three streams ranged from 9.67 to 16.11%.

Although EPT taxa were represented in all samples, the three most abundant taxa in each stream had relatively high tolerance values (TV≥6.0) except for *Prosimulium* in Pratt Creek (TV=2.6). The most abundant taxon for Lee Creek was the isopod genus *Lirceus* (TV=7.7, 24% of sample) compared to Chironomidae (TV=6.0, 31.07% and 13.36%, respectively) for Pratt Creek and Winton Spring Branch. Other common moderately tolerant taxa represented in samples were a mayfly (Ephemeroptera: *Baetis* with TV=6.0) and a caddisfly (Trichoptera: *Hydroptila* with TV=6.2).

As disturbance increases, Shannon's index and taxa evenness decrease (i.e., low values indicate possible impairment) while the HBI increases (i.e., a high value indicates possible impairment). Shannon's index accounts for both abundance and evenness of the species present, and index values are higher when all taxa in a sample are equally abundant or have high evenness. For biological data, values of Shannon's index generally ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness). Shannon's index among samples was relatively low to moderate, ranging from 1.84 to 2.48 (mean=2.16) (Table 2), but all values were above 1.64— the minimum for regional Ozark reference streams (Table 1). Taxa evenness ranged from 0.66 to 0.82 (mean=0.73). The dominance of a few tolerant taxa among samples, particularly *Lirceus* and Chironomidae, is reflected in the low to moderate Shannon's index and taxa evenness values for all three streams. HBI scores among the three streams ranged from 5.48 to 5.79 (mean=5.63), but did not exceed the maximum of 6.20 for regional Ozark reference streams.

Among taxa represented in samples, the mean tolerance value was 4.5 (range 0-10 with 10 being the most tolerant). Even though approximately 32% of all taxa collected were sensitive (TV≤3.0), intolerant taxa (TV>3.0) were more abundant in the samples as noted above (>83% of individuals collected). Sensitive taxa present in samples included the crayfish *Orconectes*; dipterans *Dixa*, *Prosimulium*, and Tipulidae; mayfly (Ephemeroptera) genera *Eurylophella*, *Leucrocuta*, and *Paraleptophlebia*; stonefly (Plecoptera) genera *Alloperla*, *Haploperla*, *Leuctra*, *Amphinemura*, and *Perlesta*; caddisfly (Trichoptera) genera *Agapetus*, *Ceratopsyche*, *Chimarra*, *Helicopsyche*, *Neophylax*, and *Pycnopsyche*; and a gastropod *Elimia* (Appendix A).

SCI scores for streams at PERI were higher under the Prairie scoring criteria with all three streams receiving scores of 20, indicating they are not impaired (Table 3). In comparison, only Lee Creek was rated unimpaired (score=18) when SCI scores were calculated using the Ozark criteria, and the other two streams were impaired (scores=12). A composite score based on the

average of the Prairie and Ozark scores resulted in unimpaired scores for all three streams (Pratt Creek=16, Winton Spring=16, and Lee Creek=19).

All water quality parameters measured in this study were within the Arkansas Pollution Control and Ecology Commission surface water quality standards for the Ozark Highlands (APCEC 2010) (Table 4). The maximum turbidity values recorded during sampling for Pratt Creek (76.30 NTU) and Winton Spring Branch (25 NTU) exceeded APCEC standards of ≤10 NTU, but these readings followed a storm event and do not reflect the baseline condition for turbidity in these streams. Dissolved oxygen levels were well above the minimum APCEC standard value of 6.0 mg/liter for all three streams (Pratt Creek=9.63 mg/liter, Winton Spring Branch=9.64 mg/liter, and Lee Creek=9.61 mg/liter). Mean stream discharge for all three streams was less than 0.02 m^3/sec at the time of sampling (Pratt Creek= 0.023 m^3/sec, Winton Spring Branch=0.158 m^3/sec, and Lee Creek=0.002 m^3/sec).

Habitat data varied broadly among sites and parameters measured (Table 5). Winton Spring Branch was deepest at a mean of 27 cm with a mean current velocity of 0.70 m/sec and Lee Creek the shallowest at 5.11 cm with a mean current velocity of 0.13 m/sec. Mean dominant substrate among riffles varied among sites from small pebble to small cobble with Winton Spring Branch being smallest (mean=22.40 cm, range=14.20-28.37 cm). In comparison the substrate in Pratt and Lee creeks was substantially larger (mean=42.33cm, range=26.48-51.33 cm, and mean=92.67cm, range=87.67-102.67 cm, respectively). Mean percent embeddedness and percent vegetation were highest at Winton Spring Branch (46.67% and 27.78%, respectively) and lowest at Lee Creek (22.78% and 7.78%, respectively). Mean percent organic material in samples was moderate ranging from 16.11% (Winton Spring Branch) to 32.22% (Lee Creek). Among all streams, mean percent filamentous algae were sparse (≤1.67%) and mean percent periphyton was 25%. Mean percent deposition among streams was considered heavy ≥40%.

Table 2. Summary statistics of mean metrics and community indices for invertebrate samples collected from Pratt Creek (2009), Winton Spring Branch (2009), and Lee Creek (2010), Pea Ridge National Military Park.

Statistic	% Intolerant	% EPT	EPT Ratio	Family Richness	Taxa Richness	EPT Richness	Shannon's Index	Taxa Evenness	HBI
Pratt Creek									
Mean	16.11	23.33	0.47	14.44	15.33	7.56	1.84	0.66	5.62
Standard Error	3.96	3.42	0.08	0.85	1.01	0.78	0.11	0.03	0.18
Minimum	3	7	0.12	10	10	4	1.15	0.46	4.63
Maximum	37	37	0.79	19	20	12	2.1	0.76	6.33
N	9	9	9	9	9	9	9	9	9
Winton Spring Branch									
Mean	9.67	42.11	0.79	14.56	15	6.11	2.15	0.82	5.48
Standard Error	1.91	3.53	0.06	1.63	1.67	0.68	0.21	0.02	0.2
Minimum	0	25	0.4	2	2	1	0.56	0.66	4.3
Maximum	16	55	1	18	18	8	2.64	0.9	6.17
N	9	9	9	9	9	9	9	9	9
Lee Creek									
Mean	13.22	37.22	0.72	22.78	24.78	15.89	2.48	0.73	5.79
Standard Error	1.65	2.25	0.02	1.01	1.39	1.31	0.04	0.01	0.1
Minimum	7	30	0.63	18	18	10	2.3	0.65	5.49
Maximum	19	50	0.79	28	33	21	2.67	0.8	6.24
N	9	9	9	9	9	9	9	9	9

Table 3. SCI scores for streams at PERI, 2009-2010 using both Prairie and Ozark stream scoring criteria, and a composite score. Scoring: 16-20 not impaired, 10-14 impaired, 4-8 very impaired.

Stream	Prairie Stream	Ozark Stream	Composite SCI Score
Pratt Creek	20	12	16
Winton Spring Branch	20	12	16
Lee Creek	20	18	19

Table 4. Mean water quality data for Pratt Creek (2009), Winton Spring Branch (2009), and Lee Creek (2010), Pea Ridge National Military Park. Data were collected with calibrated loggers (hourly for Pratt Creek and Winton Spring Branch, every 15 minutes for Lee Creek).

Water Quality Statistic	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/liter)	pH	Turbidity (NTU)
Pratt Creek					
Mean	13.18	229.97	9.63	7.27	8.20
Median	13.12	283	9.61	7.33	2.1
Standard Deviation	0.40	72.83	0.41	0.13	12.66
Minimum	12.30	58.00	8.93	6.97	0
Maximum	13.97	294.00	10.43	7.47	76.30
N	73	73	73	73	71
Winton Spring					
Mean	13.45	215.93	9.64	6.84	10.75
Median	13.44	217.00	9.64	6.86	12.30
Standard Deviation	0.15	47.87	0.07	0.12	6.81
Minimum	13.22	156.00	9.51	6.70	1.70
Maximum	13.63	277.00	9.82	7.01	25.00
N	69	69	69	69	69
Lee Creek					
Mean	14.84	0.31	9.61	7.64	1.72
Median	14.95	0.32	9.63	7.64	1.30
Standard Deviation	0.48	0.00	0.38	0.02	0.75
Minimum	14.17	0.31	8.99	7.61	1.00
Maximum	15.65	0.32	10.10	7.68	2.60
N	9	9	9	9	9
APCEC (2010) Standards	**<=29[1]**	**N/A**	**>=2 - 6[2]**	**6.0 - 9.0[3]**	**<=10[4]**

[1] Not to exceed 29 °C

[2] In <26.0 km^2 watersheds, minimum of 2 mg/L during critical season and 6 mg/L during primary season.

[3] Not to fluctuate > 1.0 pH unit over 24 hour period and not be < 6.0 or > 9.0.

[4] Not to exceed 10.0 ntu during base flows.

Table 5. Summary statistics for mean habitat variables associated with benthic samples from Pratt Creek (2009), Winton Spring Branch (2009), and Lee Creek (2010), Pea Ridge National Military Park.

Statistic	Depth (cm)	Current Velocity (m/sec)	Substrate (mm)	Embeddedness (%)[1]	Vegetation (%)[1]	Organics (%)[1]	Filamentous Algae (%)[1]	Periphyton (%)[1]	Deposition (%)[1]
Pratt Creek									
Mean	8.56	0.29	42.33	28.61	15.28	21.94	0.56	25.00	46.67
Standard Error	0.73	0.06	7.95	3.61	8.08	9.03	0.56	0.00	10.83
Minimum	7.67	0.20	26.48	25.00	0.00	5.00	0.00	25.00	25.00
Maximum	10.00	0.40	51.33	35.83	27.50	35.83	1.67	25.00	57.50
N	9	9	9	9	9	9	9	9	9
Winton Spring Branch									
Mean	27.00	0.70	22.40	46.67	27.78	16.11	0.56	25.00	40.83
Standard Error	1.17	0.03	4.24	6.25	11.15	2.22	0.56	0.00	5.83
Minimum	25.67	0.66	14.20	35.83	10.00	11.67	0.00	25.00	29.17
Maximum	29.33	0.77	28.37	57.50	48.33	18.33	1.67	25.00	46.67
N	9	9	9	9	9	9	9	9	9
Lee Creek									
Mean	5.11	0.13	92.67	22.78	7.78	32.22	0.00	25.00	40.83
Standard Error	0.29	0.02	5.00	2.22	3.09	7.22	0.00	0.00	11.68
Minimum	4.67	0.09	87.67	18.33	1.67	25.00	0.00	25.00	18.33
Maximum	5.67	0.15	102.67	25.00	11.67	46.67	0.00	25.00	57.50
N	9	9	9	9	9	9	9	9	9

[1]Absent (0%), Sparse (<10%), Moderate (10-40%), Heavy (40-75%), and Very Heavy (>75%)

Discussion

The ecological integrity of streams at PERI cannot be fully assessed at this time because there are insufficient data. The initial data were somewhat contradictory in that EPT taxa were fairly well represented among streams, but taxa richness and the percentage of intolerant taxa were relatively low. The higher scores among metrics recorded for Lee Creek may reflect the results of a different hydrologic year as it was sampled in 2010.

Although the PERI streams are considered Ozark streams, their geographic location places them in the proximity of the prairie region, suggesting some faunal overlap may occur with streams in this latter region. In addition, Pratt and Lee creeks can become intermittent during summer or have periods of drought, which may place substantial stress on the aquatic invertebrate community. Such stressors, although not indicative of poor water quality, may facilitate the establishment of a relatively tolerant invertebrate fauna with low diversity. The SCI scoring for the prairie streams and Ozark streams appears to support that contention, especially in light of the fact that there are no known anthropogenic disturbances occurring in this system. In comparison, the composite SCI scores suggest that these streams are not impaired. If the Ozark SCI scoring is used exclusively, it suggests that Pratt Creek and Winton Spring Branch may be moderately impaired. Other supporting evidence, including the occurrence of the rare and environmentally sensitive Oklahoma salamander (*Eurycea tynerensis* Moore and Hughes) in all three streams, suggests they are not impaired. In addition, the presence of environmentally sensitive red alga (Rhodophyta, *Batrachospermum*) also indicates these streams are not impaired. The low percentage of filamentous green algae and periphyton among streams suggests that nutrient inputs to these systems are low.

Natural conditions, such as intermittent flow in Pratt and Lee creeks, may naturally affect the diversity of their respective invertebrate communities. Although seasonally intermittent, these streams receive inputs from springs, which may help provide adequate water flows to sustain the less tolerant species during periods of low flow. Springs, such as Winton Spring Branch, are known for low diversity due to nearly constant water temperatures and more consistent year-round groundwater inputs. Only additional monitoring will allow insight into any patterns that may exist in and among community structure in these streams.

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Appendix A: Aquatic invertebrate data collected from Pea Ridge National Military Park 2009-2010.

Table A-1. Aquatic invertebrate data collected from Pratt Creek (2009), Pea Ridge National Military Park. TV is tolerance value. Riffles sampled are numerically designated as 1-3 and L, M and R refer to left, middle and right samples taken in a riffle.

						Pratt Creek									
Phylum	**Class**	**Order**	**Family**	**Genus**	**TV**	**1-L**	**1-M**	**1-R**	**2-L**	**2-M**	**2-R**	**3-L**	**3-M**	**3-R**	**TOTAL**
Annelida	Oligochaeta				8.0			1	1		1	11		1	15
Arthropoda	Arachnoida	Hydracarina			5.7		3	2	3	1	2	1		2	14
Arthropoda	Crustacea	Decapoda	Cambaridae		6.0	1						1			2
Arthropoda	Crustacea	Isopoda	Asellidae	Lirceus	7.7	75	69	84	99	54	63	44	30	87	605
Arthropoda	Insecta	Coleoptera	Psephenidae	Ectopria	4.3	1	1	3	1					3	9
Arthropoda	Insecta	Collembola								3	2	2	2	2	11
Arthropoda	Insecta	Diptera							1		1				2
Arthropoda	Insecta	Diptera	Ceratopogonidae		6.0							1			1
Arthropoda	Insecta	Diptera	Chironomidae		6.0	35	108	80	19	73	30	104	171	123	743
Arthropoda	Insecta	Diptera	Empididae	Hemerodromia	6.0					1			1		2
Arthropoda	Insecta	Diptera	Simuliidae	Prosimulium	2.6	21	52	141	30	12	95			9	360
Arthropoda	Insecta	Diptera	Tipulidae	Hexatoma	4.7									1	1
Arthropoda	Insecta	Diptera	Tipulidae	Pseudolimnophila	7.3				2			1			3
Arthropoda	Insecta	Diptera	Tipulidae	Tipula	7.7				2		1		1		4
Arthropoda	Insecta	Ephemeroptera	Baetidae		4.0			24	22	10	19	3	11	24	113
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella	3.6	18	31	22	4	15	58		2	14	164
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	6.0	35	13		3	5	10			17	83
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema	3.4	20		4	5		9	5		4	47
Arthropoda	Insecta	Megaloptera	Sialidae	Sialis	7.5									1	1
Arthropoda	Insecta	Odonata	Coenagrionidae	Argia	8.7		1		1						2
Arthropoda	Insecta	Plecoptera			2.0	8		1	14	3	4	2	9	5	46
Arthropoda	Insecta	Plecoptera	Nemouridae	Amphinemura	3.4		1								1
Arthropoda	Insecta	Plecoptera	Perlidae		1.0								1	1	2
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Agapetus	0.0									1	1
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	0.0	4	1		3	3	1	3		7	22
Arthropoda	Insecta	Trichoptera	Hydropsychidae		4.0		2								2
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche	4.0	2	4	5	5	10	7		1	3	37
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila	6.2	1	21	9	9	9	2			2	53
Arthropoda	Insecta	Trichoptera	Limnephilidae	Pycnopsyche	2.3			1						1	2
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarra	2.8				1	1					2
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Psychomyia	3.3						2			2	4
Mollusca	Bivalvia	Veneroidea	Sphaeriidae	Pisidium	6.8		1		2			1	2		6
Mollusca	Gastropoda	Bassommatophora	Physidae	Physella	9.1	1					1				2
Nematomorpha					5.0	2	1					1			4
Platyhelminthes	Turbellaria	Tricladida	Planariidae	Dugesia	7.5	14	36	11	8	18	13	11	16	10	137
						238	345	388	235	218	321	191	247	320	2503

Table A-2. Aquatic invertebrate data collected from Winton Spring Branch (2009), Pea Ridge National Military Park. TV is tolerance value. Riffles sampled are numerically designated as 1-3 and L, M and R refer to left, middle and right samples taken in a riffle.

						Winton Spring Branch									
Phylum	**Class**	**Order**	**Family**	**Genus**	**TV**	**1-L**	**1-M**	**1-R**	**2-L**	**2-M**	**2-R**	**3-L**	**3-M**	**3-R**	**TOTAL**
Annelida	Oligochaeta				8.0	11	4	15	5		9		18	7	69
Arthropoda	Arachnoida	Hydracarina			5.7	2	5	3	5	8	1		2		26
Arthropoda	Crustacea	Amphipoda			4.0						2				2
Arthropoda	Crustacea	Amphipoda	Hyalellidae	Hyalella	7.9	4	6	3	1	38				2	54
Arthropoda	Crustacea	Isopoda	Asellidae	Lirceus	7.7	47	91	14	45	28	26		29	9	289
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus	2.7	19	9	10	8					3	49
Arthropoda	Insecta	Coleoptera	Psephenidae	Ectopria	4.3	11	3	1		1			1		17
Arthropoda	Insecta	Collembola				1	2	2			3		2	3	13
Arthropoda	Insecta	Diptera	Ceratopogonidae		6.0			1							1
Arthropoda	Insecta	Diptera	Chironomidae		6.0	21	30	17	57	189	17		6	26	363
Arthropoda	Insecta	Diptera	Empididae	Hemerodromia	6.0	1			1						2
Arthropoda	Insecta	Diptera	Simuliidae	Prosimulium	2.6				7						7
Arthropoda	Insecta	Diptera	Simuliidae	Simulium	4.4					3		3	2	8	16
Arthropoda	Insecta	Diptera	Tipulidae	Tipula	7.7				1					1	2
Arthropoda	Insecta	Ephemeroptera	Baetidae		4.0	17	40	5	43	10	24		19	11	169
Arthropoda	Insecta	Ephemeroptera	Baetidae	Acentrella	3.6	9	4	3	12		19		35	10	92
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	6.0		8	13					11	6	38
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema	3.4						2				2
Arthropoda	Insecta	Odonata	Coenagrionidae	Argia	8.7	5	7	1	6	9	2		7	9	46
Arthropoda	Insecta	Plecoptera			2.0					2					2
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Agapetus	0.0	1									1
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	0.0	9	5	7	41	13	26		16	15	132
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	6.6								8		8
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsyche	4.0	10	3		11	7	6	1		10	48
Arthropoda	Insecta	Trichoptera	Hydroptilidae		4.0		6	4							10
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila	6.2	66	35	10	69	92	11		15	32	330
Arthropoda	Insecta	Trichoptera	Limnephilidae	Pycnopsyche	2.3	1									1
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropus	3.5		1	1	1	1	2		1		7
Mollusca	Bivalvia	Pelecypoda	Sphaeriidae		8.0								6		6
Mollusca	Bivalvia	Veneroidea	Sphaeriidae	Pisidium	6.8	1	7	3	1	6	5			10	33
Mollusca	Gastropoda				7.0				1						1
Nematomorpha					5.0			1							1
Platyhelminthes	Turbellaria	Tricladida	Planariidae	Dugesia	7.5	20	17	5	49	21	11		15	24	162
						256	283	119	364	428	166	4	193	186	1999

Table A-3. Aquatic invertebrate data collected from Lee Creek (2010), Pea Ridge National Military Park. TV is tolerance value. Riffles sampled are numerically designated as 1-3 and L, M and R refer to left, middle and right samples taken in a riffle.

						Lee Creek									
Phylum	**Class**	**Order**	**Family**	**Genus**	**TV**	**1-L**	**1-M**	**1-R**	**2-L**	**2-M**	**2-R**	**3-L**	**3-M**	**3-R**	**TOTAL**
Annelida	Oligochaeta				8.0	32	6	40	1	23	35	1	1		139
Arthropoda	Arachnoida	Hydracarina			5.7		2					6	3		11
Arthropoda	Crustacea	Decapoda	Cambaridae	Orconectes	2.7	1		5	1	1	2	2		1	13
Arthropoda	Crustacea	Isopoda			8.0	152	24	61	13	18	59	70	15	12	424
Arthropoda	Crustacea	Isopoda	Asellidae	Lirceus	7.7	281	82	148	48	67	162	71	9	81	949
Arthropoda	Insecta	Coleoptera	Dryopidae	Helichus	5.4									1	1
Arthropoda	Insecta	Coleoptera	Dytiscidae		5.0	11	1	7	1	10	11	18	2	3	64
Arthropoda	Insecta	Coleoptera	Dytiscidae	Laccophilus	10.0					1					1
Arthropoda	Insecta	Coleoptera	Elmidae	Optioservus	2.7				1	4	3				8
Arthropoda	Insecta	Coleoptera	Elmidae	Stenelmis	5.4		1	9		2	3				15
Arthropoda	Insecta	Coleoptera	Psephenidae	Ectopria	4.3	24	3	10	9	15	54	6	2	10	133
Arthropoda	Insecta	Collembola					2				1				3
Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia/Palpomyia	6.0	1	1	3			1	1	1		8
Arthropoda	Insecta	Diptera	Ceratopogonidae	Mallochohelea	6.0		2				1				3
Arthropoda	Insecta	Diptera	Chironomidae		6.0	103	34	70	24	46	88	85	45	36	531
Arthropoda	Insecta	Diptera	Dixidae									2		4	6
Arthropoda	Insecta	Diptera	Dixidae	Dixa	2.8		8	1			5			1	15
Arthropoda	Insecta	Diptera	Dolichopodidae		4.0				1						1
Arthropoda	Insecta	Diptera	Empididae	Hemerodromia	6.0						1				1
Arthropoda	Insecta	Diptera	Empididae	Roederiodes			2								2
Arthropoda	Insecta	Diptera	Simuliidae	Simulium	4.4		1				3	2	11	2	19
Arthropoda	Insecta	Diptera	Tipulidae		3.0	4		1		1	2				8
Arthropoda	Insecta	Diptera	Tipulidae	Hexatoma	4.7						1				1
Arthropoda	Insecta	Diptera	Tipulidae	Pseudolimnophila	7.3	13	2	5	3	2	19			2	46
Arthropoda	Insecta	Diptera	Tipulidae	Tipula	7.7	1	2		2	1	2	2			10
Arthropoda	Insecta	Ephemeroptera	Ameletidae	Ameletus	7.0	1									1
Arthropoda	Insecta	Ephemeroptera	Baetidae		4.0	40	15	41	19	8	8	36	27	48	242
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	6.0	90	1	6	11	75	142	40	18	22	405
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Eurylophella	3.0	1			1	1	1				4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae		4.0		2			1					3
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Leucrocuta	0.0	1		2		1	1	1			6
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenacron	7.1	1			1		1				3
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Stenonema	3.4	2				2			1	1	6
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		2.0			7							7
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Leptophlebia	6.4	26	8	1	6	9	21	4		2	77
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Paraleptophlebia	1.2			1		2					3

Table A-3 (continued). Aquatic invertebrate data collected from Lee Creek (2010), Pea Ridge National Military Park. TV is tolerance value. Riffles sampled are numerically designated as 1-3 and L, M and R refer to left, middle and right samples taken in a riffle.

						Lee Creek									
Phylum	**Class**	**Order**	**Family**	**Genus**	**TV**	**1-L**	**1-M**	**1-R**	**2-L**	**2-M**	**2-R**	**3-L**	**3-M**	**3-R**	**TOTAL**
Arthropoda	Insecta	Hemiptera	Gerridae		5.0	1						1			2
Arthropoda	Insecta	Hemiptera	Veliidae	Microvelia	6.4				1	1		2	1	1	6
Arthropoda	Insecta	Megaloptera	Sialidae	Sialis	7.5			1							1
Arthropoda	Insecta	Odonata				1		1							2
Arthropoda	Insecta	Odonata	Gomphidae		7.0	6					14				20
Arthropoda	Insecta	Odonata	Gomphidae	Stylogomphus	4.8									1	1
Arthropoda	Insecta	Plecoptera			2.0	1		3	1	2		3			10
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Alloperla	1.4						1				1
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Haploperla	1.4			1				1			2
Arthropoda	Insecta	Plecoptera	Leuctridae		0.0	50	24	47	12	13	76	15	4		241
Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctra	0.7	26	6	5	6	3	26	1		1	74
Arthropoda	Insecta	Plecoptera	Nemouridae		0.0			1			7				8
Arthropoda	Insecta	Plecoptera	Nemouridae	Amphinemura	3.4	2	4				6		4		16
Arthropoda	Insecta	Plecoptera	Perlidae		1.0	2	1	2	1	2	2	2		1	13
Arthropoda	Insecta	Plecoptera	Perlidae	Perlesta	0.0	6	2	8	2	1	8	7	2	7	43
Arthropoda	Insecta	Trichoptera				1	3	6	2	1	1	1	2	1	18
Arthropoda	Insecta	Trichoptera	Glossosomatidae		0.0				1				1		2
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Agapetus	0.0					1	1	1			3
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Helicopsyche	0.0	1			2			2	6	3	14
Arthropoda	Insecta	Trichoptera	Hydropsychidae		4.0			4		1					5
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Ceratopsyche	1.4	2	1	2	4	2	5			4	20
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Cheumatopsyche	6.6			1							1
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptila	6.2	3		8	4	2	7	29	30	17	100
Arthropoda	Insecta	Trichoptera	Limnephilidae	Ironoquia	7.3							1			1
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarra	2.8		2	5			7				14
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropus	3.5	6	4	7	2	4	7				30
Arthropoda	Insecta	Trichoptera	Uenoidae	Neophylax	1.6			1							1
Mollusca	Bivalvia	Veneroidea	Sphaeriidae	Sphaerium	7.7									2	2
Mollusca	Gastropoda	Bassommatophora	Ancylidae	Ferrissia	6.9	1									1
Mollusca	Gastropoda	Bassommatophora	Physidae	Physella	9.1	4	1	3	11	3	11	35	8	14	90
Mollusca	Gastropoda	Neotaenioglossa	Pleuroceridae	Elimia	2.5				1						1
						898	247	524	192	326	806	448	193	278	3912